

Achieving High Stability and Efficiency in the Next Generation of Adiabatic Demagnetization Refrigerators

Completed Technology Project (2014 - 2015)



Project Introduction

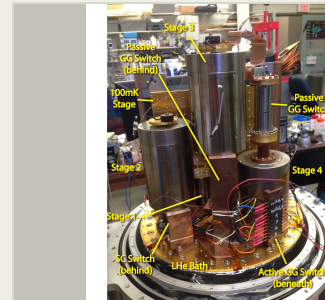
Large cryogenic detector arrays drive astrophysical science capabilities from millimeter to X-ray wavelengths. The continuous adiabatic demagnetization refrigerator (CADR) is ideal to support these space-borne arrays because it has no moving parts or cryogenics, it achieves temperatures <0.1 K, and it has low mass and very high efficiency. We will implement and test two technologies that improve the next generation of CADRs by boosting the overall efficiency and stability.

Ordinary refrigeration uses mechanical compression and expansion to interact with kinetic degrees of freedom in a gas. The magnetic refrigerators investigated here use magnetic fields to interact with spin degrees of freedom in a crystal. The magnets are cryogenic and superconducting, and the crystal is a material with large magnetocaloric effects like gadolinium gallium garnet. We cool the system using liquid helium, but mechanical cryocoolers would be used in space applications. Continuous cooling can be achieved by cycling pairs of magnetic coolers. In high-sensitivity bolometer systems, stability $\sim 10^{-5}$ is required, presenting a challenge for the control of cycling. We are investigating materials and algorithms that permit more stable and efficient operation of these systems.

Anticipated Benefits

Science from millimeter to X-ray wavelengths is driven by increasingly larger and colder focal planes of cryogenic detectors. Superconducting Transition-Edge Sensors (TES) and Kinetic Inductance Detectors are based on 0.1 K focal planes that have a few μW of typical heat load. The technologies developed here will improve the stability and efficiency of the cryogenic systems needed to support these arrays.

Any instruments that require temperatures ~ 0.1 K could take advantage of magnetic cooling. These can be combined with cryocoolers to achieve systems that are compact, stable, efficient, and able to operate without expendable cryogenics.



A four-stage continuous cooler for reaching temperatures < 0.1 K from a 4.2 K bath.

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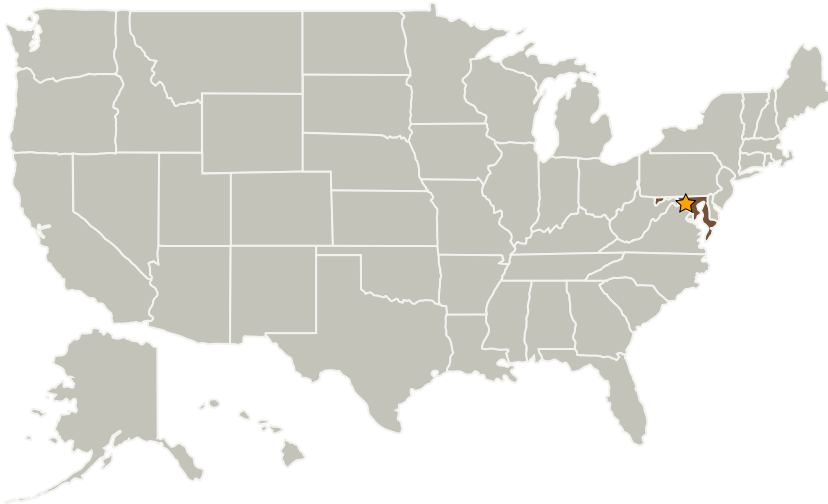
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Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Goddard Space Flight Center (GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations

Maryland

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Independent Research & Development: GSFC IRAD

Project Management

Program Manager:

Peter M Hughes

Project Manager:

Stanley D Hunter

Principal Investigator:

Eric R Switzer

Co-Investigators:

Peter J Shirron

Dan F Sullivan

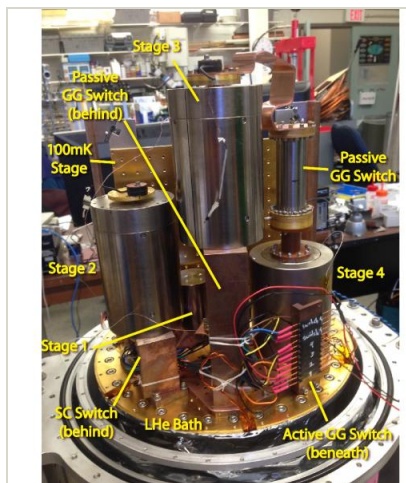
Mark O Kimball

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Images



A continuous adiabatic demagnetization refrigerator

A four-stage continuous cooler for reaching temperatures < 0.1 K from a 4.2 K bath.

(<https://techport.nasa.gov/image/4193>)

Links

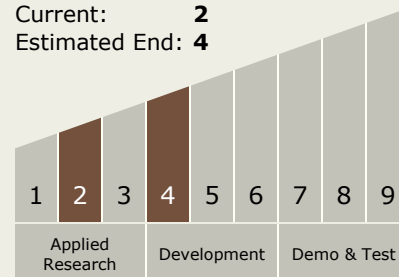
NTR 1436814776
(no url provided)

Project Website:

<http://sciences.gsfc.nasa.gov/sed/>

Technology Maturity (TRL)

Start: 2
Current: 2
Estimated End: 4



Technology Areas

Primary:

- TX14 Thermal Management Systems
 - └ TX14.1 Cryogenic Systems
 - └ TX14.1.3 Thermal Conditioning for Sensors, Instruments, and High Efficiency Electric Motors